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(Arnold B. Dompieri)

2875

Docket No.: DAVIDK 3.9-002 CONT
(PATENT)

#7
Scott
12-18-02

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of:
Worsdell et al.

Application No.: 10/047,521

Group Art Unit: 2875

Filed: November 13, 2001

Examiner: Sharon Payne

For: IMPROVEMENTS IN LIGHTING

CLAIM FOR PRIORITY AND SUBMISSION OF DOCUMENTS

Commissioner for Patents
Washington, DC 20231

Dear Sir:

Applicant hereby claims priority under 35 U.S.C. 119 based on the following prior foreign application filed in the following foreign country on the date indicated:

<u>Country</u>	<u>Application No.</u>	<u>Date</u>
Great Britain	9911943.0	May 21, 1999

In support of this claim, a certified copy of the original foreign application is filed herewith.

Dated: November 25, 2002

Respectfully submitted,

By

Arnold B. Dompieri

Registration No.: 29,736

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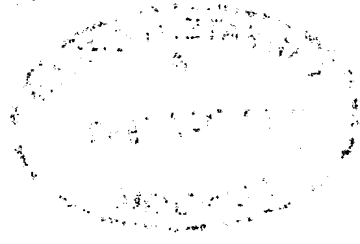


Signed

Stephen Hordley

Dated 11 October 2002

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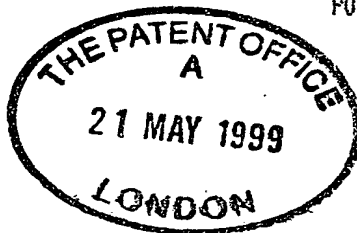
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Request for grant of a patent

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1. Your reference

JMC/NPT/4957

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21 MAY 1999

9911943.0

3. Full name, address and postcode of the or of each applicant (underline all surnames)

AVIMO LIMITED
LISIEUX WAY
TAUNTON
SOMERSET
TA1 2JZ

Patents ADP number (if you know it)

If the applicant is a corporate body, give the country/state of its incorporation

6628325001 Rdes

4. Title of the invention

IMPROVEMENTS IN LIGHTING

5. Name of your agent (if you have one)

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

DAVID KELTIE ASSOCIATES
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EC4A 1AG

Patents ADP number (if you know it)

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6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know it) the or each application number

Country

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Date of filing

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Number of earlier application

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Yes

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Continuation sheets of this form

Description 12

Claim(s) 4

Abstract

Drawing(s) 5

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Priority documents

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Statement of inventorship and right to grant of a patent (Patents Form 7/77)

Request for preliminary examination and search (Patents Form 9/77)

One

Request for substantive examination (Patents Form 10/77)

Any other documents (please specify)

11. I/We request the grant of a patent on the basis of this application.

Signature

Date

David Keltie Associates

DAVID KELTIE ASSOCIATES

21 MAY 1999

12. Name and daytime telephone number of person to contact in the United Kingdom

Judith Caldwell 0171 583 6000

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IMPROVEMENTS IN LIGHTING

5 This invention relates to improvements in lighting, particularly to warning lights for external use on aircraft.

10 External aircraft lights, broadly speaking, fall into two main categories. The first is for the purpose of illuminating the space around the aircraft to improve visibility for the pilot, of which landing lights are an example. The second is to act as warning lights for the purpose of providing a visible warning of the aircraft's presence to observers both on the ground and in other aircraft.

15 Essentially, there are two types of external aircraft warning lights: anti-collision lights and navigation lights.

20 Anti-collision lights are intended to attract the attention of observers, especially in low light conditions and, accordingly, these lights are designed to emit very bright light all around the aircraft and are usually pulsed so that they flash at between about 40 to 100 times a minute. In addition to the necessity of emitting light all around the aircraft, regulations imposed by the relevant national governing aviation bodies – such as the Civil Aviation Authority (CAA) in the UK and the Federal Aviation Authority (FAA) in the USA – stipulate that there should be a low divergence in the vertical plane. Accordingly, anti-collision lights ideally emit light in a substantially horizontal disk pattern.

25 Once an observer is made aware of the presence of an aircraft by its anti-collision lights, the navigation lights provide an indication of the orientation of the aircraft. Typically, an aircraft carries at least three navigation lights: a green light on the starboard side, a red light on the port side and a white light on the rear of the aircraft. For example, these may be located respectively on the end of the wings and on the tail of an aeroplane. They are less bright than anti-collision lights and are generally illuminated continuously in use.

30 In contrast with anti-collision lights which are required to be visible around 360° in a horizontal plane, both the horizontal and vertical distribution of emitted light from a navigation light are important. This is because each navigation light is required to emit light in a horizontal plane around the aircraft and at a minimum intensity which varies according to angular direction. For example, the red and green lights are not only required to emit bright light directly forward from the aircraft, but are also required to emit light to

the port side and the starboard side respectively, albeit of a lower minimum intensity than in the forward direction.

In fact, required angular distributions of the FAA of light for a starboard navigation light are shown in Figure 1. Figure 1a shows the required azimuthal distribution and Figure 1b shows the required angular distribution in the vertical plane. It will be appreciated that the corresponding azimuthal distribution for a port light is merely the mirror image of that shown for the starboard light. The minimum light intensity at various azimuthal angles is shown (0° corresponding to the direction in which the aircraft faces). The FAA requires a minimum light intensity of 40 candela between 0° and 10° , 30 candela between 10° and 20° and 5 candela between 20° and 110° .

A variety of light sources are used in external aircraft lights, traditionally filament lamps and xenon flash tubes have been employed, but increasingly arrays of light emitting diodes (LEDs) are being used due to their greater reliability, robustness, lifetime and their low cost.

It will be appreciated that all these light sources emit uncollimated light that diverges over wide angles. As discussed, this can create problems, particularly for warning lights, where there is a need to satisfy the light emission regulations imposed by the relevant governing aviation authorities. Accordingly, it has been common practice to provide reflectors, for example, in order to divert the emitted light in the desired manner. However, use of rear reflectors is not an option when the LEDs are surface mounted as is usually the case.

As mentioned, conventional LEDs generally emit light with a smooth angular variation over a wide angle, so that it would appear approximately circular if included in Figures 1a and 1b. In fact, LED lamps emit light to about 60° on either side azimuthally of the forward direction. Thus in order to cover the required azimuthal emission range over 0° to 110° , port and starboard lights must be turned away from the forward direction of the aircraft. They are typically pointed 35° away from the forward direction and, consequently, the brightest light is not emitted in the forward direction of the aircraft as would be desired. Consequently, the light intensity is too weak to meet the FAA required intensity in the forward direction.

Accordingly, a replacement bulb for a typical navigation light that includes both visible LEDs and IR LEDs for covert operations, such as that shown in WO98/21917 A1 to LFD Limited, would produce a diverging illumination pattern.

Collimation of light emitted by LEDs in an external aircraft light is known from GB 2,307,977 A1 to Chapman and Bloxham. In the particular embodiment disclosed, the aircraft light is a landing light comprising a central halogen lamp for producing a visible beam of light surrounded by a ring of IR LEDs. The landing light can be switched between normal and covert modes. Some of the IR LEDs have discrete plano-convex lenses associated with them, these lenses being individually mounted on a plate for the purpose of collimating the light emitted from the diode underneath into a narrow beam, whilst others are allowed to emit IR light in the normal way through corresponding apertures in the plate to provide area illumination for pilots wearing night vision goggles (NVGs).

However, Chapman and Bloxham merely collimates the light as it propagates through the lenses, and offers no suggestion of or assistance with directing the emitted light into a desired angular distribution.

The Applicant has sought to address the aforementioned disadvantages associated with LED warning lights. Accordingly, it is an object of the invention to provide a warning light for an aircraft which emits light with an angular distribution peaked in the forward direction.

From a first aspect, therefore, the invention resides in a warning light for an aircraft comprising an array of LEDs and an optical unit held in front of the LED array, the optical unit incorporating optical means for propagating fractions of the light emitted from the LEDs in selected directions in accordance with a predetermined angular distribution.

By means of the present invention, the divergent light emitted by the LEDs that is incident on the optical unit propagates through the optical means and emerges with varying intensity over a range of angles. In this way, it is possible to divert a significant proportion of the light, which would otherwise be emitted to the sides, in a forward direction and consequently permits the light far to exceed the minimum intensity required in front of the aircraft. This is in sharp contrast to the conventional naked LED array in which the minimum forward intensity is not met.

Expressed in another way, the invention resides in a warning light for an aircraft comprising an array of LEDs and an optical unit held in front of the LED array, the optical unit incorporating optical means which redirects at least some of the light which would otherwise be emitted from the LEDs in a substantially lateral direction relative to the

orientation of the aircraft, and emits a fraction of that light in a substantially forward direction.

In a preferred embodiment, substantially all of the light emitted from the LEDs positioned directly beneath the optical unit is incident upon it. In this way, almost none of the light emitted by the LEDs is wasted and all of the light is available to be propagated as desired.

The optical unit may incorporate either or both refractive or diffractive optical means in order to propagate the light selectively.

10 Conveniently, the optical unit comprises refractive optical means including a first element in the form of a plurality of lenses to collect the incident light. Advantageously, each LED has an associated lens. In a still further preferred embodiment, each lens is disposed immediately in front of its associated LED, so that the optical unit includes an array of lenses to match the array of LEDs. Preferably, the lenses are convex lenses and are
15 provided on the surface of the optical unit facing the LED array.

Most preferably, each convex lens collects the divergent light emitted from its associated LED, which is effectively a point source producing spherical waves, and directs the light towards a second element of the optical means. In a further preferred embodiment, the
20 second element of the optical means also comprises refractive means, for example in the form of one or more prisms, triangular prisms being particularly preferred. In general, such prisms will be provided on the opposite surface of the optical unit relative to the array of lenses. The light emerging from the or each prism, and hence the optical unit, is refracted and the angle of refraction will depend upon the angle of incidence at the appropriate face
25 of the prism. Accordingly, the shape and configuration of the lenses and prism(s) are coordinated to provide the required angular distribution of the emergent light.

A diode array in a starboard or port navigation light will usually be pointed at an angle away from the forward direction of the aircraft in order to provide the necessary
30 illumination around to 110° in the horizontal plane as shown in Figure 1a. This azimuthal angle must of course be at least 20° , but historically has been set at about 35° to provide the required intensity of illumination. Accordingly, in the present invention it may be appropriate to provide at least one prism which serves to direct at least some light to the peripheral higher angles of the required distribution.

35

In a particularly preferred embodiment, the convex lenses are uniform and produce plane waves which are subsequently incident on a plurality of prisms. However, the lenses may

alternatively act to focus or collimate the emitted light towards the or each prism. As the light propagates from each convex lens in a common direction, varying the angles of the prism faces in either the horizontal plane and/or the vertical plane results in a variation of the direction of propagation of light from the optical unit either horizontally and/or
5 vertically. Hence, careful selection of the angles of the prism faces allows the required angular distribution to be emitted by the warning light.

Advantageously, the optical means is formed as an integral part of the optical unit. For example, the optical unit may comprise a moulded plastic element in which the lenses and
10 prisms are formed on the respective surfaces during the moulding process.

The LEDs may be arranged in any desired configuration, for example in a square or rectangular array to form rows and columns. However, the LEDs may equally be arranged in a circle, either radially or concentrically.

Furthermore, the LEDs may comprise a plurality of groups of LEDs, the groups being connected in parallel and each group comprising a plurality of LEDs connected in series. This arrangement incorporates built-in redundancy which prevents catastrophic failure of the LED array because if one diode fails, the whole unit will not also fail. Rather, only the
20 group or string of diodes which contains the defective LED will fail and the remaining strings will be unaffected. Each string of LEDs may form a row of the square array.

Of course, a square array of LEDs will desirably require a corresponding square array of lenses, which in turn desirably requires a corresponding arrangement of prisms. If a
25 separate prism is to be provided for each lens, these too must be arranged in a corresponding square array. The Applicant has had the foresight to appreciate that a row or column of LEDs can be assigned to emit light in a particular desired propagation direction in either the horizontal or vertical plane. If no particular angular distribution is desired in the other plane, a prism of uniform cross-section can be positioned above the row or
30 column of LEDs. On the other hand, if both horizontal and vertical redirection is required, a prism having a varying cross-section along its length can be positioned above the row or column. In such an arrangement, the prisms may form a series of ridges along a surface of the optical unit, for example creating a saw-tooth appearance when viewed in cross-section.

When the LEDs are arranged into a plurality of strings to form a square array, each string comprising a row of the array, the prisms advantageously extend along the columns of

LEDs (i.e. orthogonal to the strings). This has the advantage that should a string of LEDs fail, light will be lost across a range of propagation directions merely reducing the intensity by a small amount in each direction. Conversely, if the prisms extended along the length of the strings in their rows, a string failing could result in a significant, or even total, loss of light in one of the propagation directions and therefore offers a less preferred arrangement.

The warning light according to the invention most conveniently comprises a single optical unit associated with a single LED array. This maximises the inherent benefit of making an array of lenses rather than individual lenses, viz. it is easier and less expensive to manufacture the optical unit and it is also easier and less expensive to assemble the warning light. Preferably, the optical or lens unit is made from moulded plastic.

From another aspect, the invention resides in an optical unit for use with an LED array in an aircraft warning light, the unit comprising optical means for propagating fractions of the light emitted from the LEDs in selected directions in accordance with a predetermined angular distribution. Expressed in another way, the invention resides in an optical unit for use with an LED array in an aircraft warning light, the unit comprising optical means which redirects at least some of the light which would otherwise be emitted from the LEDs in a substantially lateral direction relative to the orientation of the aircraft, and emits a fraction of that light in a substantially forward direction.

More especially, this invention further resides in an optical unit for use with an LED array in an aircraft warning light, the unit comprising a transparent body having first and second opposed faces, the first face being provided with a plurality of convex lenses and the second face being provided with at least one prism, the relative disposition of the or each prism and the convex lenses being such as to propagate light from the unit in accordance with a predetermined angular distribution.

Preferably, the body is made of plastic and formed with integral lenses and prism or prisms such as by moulding. In this way, the cost of manufacture for the unit can be minimised. Polycarbonate and acrylic materials are particularly suitable for providing the desired optical quality and strength, and do not readily distort when subject to heat generated by the LEDs.

Typically, the LEDs are surface mounted on a ceramic substrate and the optical unit is held in front of the LED array on its substrate. The optical unit may be in contact with the LED

array, for example the LEDs may be encapsulated in a potting compound against which the optical unit abuts. Alternatively, the optical unit and the LED array, whether or not in a potting compound, may be separated. Any gap created between the optical unit and LED array is also advantageous as it allows a channel for air to circulate therebetween, allowing more of the heat produced by the LEDs to be dissipated through convection and so reducing the heating effect on the optical unit.

The separation of LEDs and the optical unit will be predetermined according to the design of the optical unit. In particular, this separation is ideally such that the maximum amount of emitted light from the LEDs is collected. The spacing between the LEDs and the optical unit may generally be up to 5 mm, more preferably between 0.5 mm to 2 mm. Indeed, a gap of about 1 mm is particularly suitable as it is sufficiently close to the LEDs to ensure optimum light collection.

The fixed separation of optical unit and LEDs can be maintained by a spacer. This spacer may either be separate or may be integral with either the optical unit, the LED array or the potting compound. For example, a rim may be provided around the perimeter of the optical unit such that it abuts against the perimeter of the ceramic substrate on which the LED array is mounted. Conversely, the rim may be integral with the ceramic substrate. Alternatively, the required depth of potting compound may be increased to form a spacer. In this way, correct assembly of the LED array and the optical unit is simplified because the required spacing is automatically achieved.

The LED array and the optical unit may be supplied together as a single component, complete with spacer, and hereinafter referred to as a lamp unit. Such a lamp unit may be fitted as a replacement for an existing LED array, or may be fitted as apart of an entire light assembly complete with housing.

Preferably, the warning light includes a separate cover to protect the optical unit from the elements. Forming the optical unit integrally with the cover, so that the prisms are on the outer surface of the cover, is undesirable. Obviously, the cover must comprise a transparent window and must not adversely affect light emission from the optical unit.

As will be appreciated, an aircraft moves at considerable speed relative to its surroundings. Frequent high-speed impacts will occur with debris, e.g. rubber left on runways or ice in the atmosphere. Such impacts inevitably cause damage to a light's protective cover, resulting in chipping or cracking of the window. If the outer surface of the window bears

prisms or otherwise acts as a lens, the chipping or cracking would be to the detriment of the optical performance of the warning light. Moreover, the inevitable accumulation of dirt between the prisms would also be detrimental. Accordingly, it is advantageous for the windows to be relatively inexpensive as they must be replaced periodically.

5 It will be appreciated that in addition to use on aircraft navigation lights, similar lamp units may be used in anti-collision lights. In this regard, a series of such units may be positioned so that the lamp units face out in a radial arrangement to provide the required horizontal illumination. A hexagonal arrangement of lamp units provides a convenient means of
10 achieving the desired light distribution. Of course, the optical unit may be adapted to provide a different angular distribution of light than is appropriate for a navigation light.

Also, in order to provide a covert capability, one or more IR LEDs may be included in the LED array which forms part of the warning light of the invention. Alternatively, IR LEDs
15 or other IR light sources may be provided separately from the lamp unit.

In order that the invention can be more readily understood, reference will now be made, by way of example only, to the accompanying drawings in which:

20 Figure 1a is a polar plot of the minimum required azimuthal angular distribution of light for a starboard navigation light stipulated by the FAA;

Figure 1b corresponds to Figure 1a, but for the vertical plane rather than the horizontal plane;

25 Figure 2 is a front view of a navigation light assembly 1 according to the present invention;

30 Figure 3 shows the navigation light assembly 1 of Figure 2 from above and corresponds to a transverse sectional view along line X-X of Figure 2;

Figure 4 is a view of the navigation light assembly 1 of Figure 2 from one side showing the external portion 7, but with the window 8 and housing 9 removed;

35 Figure 5 is a view of a navigation light assembly 1 from the opposite side to that of Figure 4;

Figure 6 is a transverse sectional view of the lamp unit 10 according to the present invention;

Figure 7 is a front view of the LED array 23;

Figure 8 is a transverse sectional view of the optical unit 22 according to a further embodiment of the invention; and

Figure 9 is a sectional view of a second embodiment of the present invention.

Figures 2 to 5 show a wing navigation light assembly 1 for an aircraft according to the present invention. The navigation light assembly 1 can either be used as a replacement for existing lights on an aircraft or for fitting to new aircraft.

To fit the navigation light assembly 1 to an aeroplane wing, the assembly is placed with its flat surface 2 against a surface of the wing with its wider end 3 facing the direction of travel. In the illustrated embodiment, the navigation light assembly 1 is attached to the end of a wing by a fastener 4 with its flat surface 2 disposed vertically against an end surface of the wing, and so terms like top and bottom should be construed accordingly.

The navigation light assembly 1 has an external shape corresponding to a bisected teardrop which is advantageous in terms of aerodynamics. A hollow cylinder 5 extends from a metal mounting plate 6 near the front half of the light assembly 1. When fitted to an aircraft, the hollow cylinder 5 fits into an aperture in the wing and provides a duct for routing electrical cables.

The external portion 7 of the navigation light assembly 1 is comprised of a transparent plastic window 8 and a metal housing 9, both of which attach to the metal mounting plate 6. The window 8 is disposed at the front of the navigation light assembly 1 and the opaque housing 9 is disposed at the rear.

A lamp unit 10, a radiator 11 and a covert light 12 are housed within the external portion 7. The rectangular slab-like lamp unit 10 is forward-facing and is disposed towards the front of the assembly 1 behind the transparent window 8 so that the lamp unit 10 is clearly visible through the window 8.

A first side 13 of the lamp unit 10 is mounted to an angled face 14 of the mounting plate 6

directly in front of an aperture 15, and a second side 16 of the lamp unit 10 is mounted to a top corner 17 of the radiator 11 above and behind the aperture 15. The lamp unit 10 is, therefore, tilted at an angle away from the forward direction of the aircraft so that it points forwards and to the side at an azimuthal angle of approximately 35°.

The tilt of the lamp unit 10 creates a cavity 18 between the lamp unit 10 and the radiator 11 in communication with the aperture 15 so that cables can be passed directly through the aperture 15 into the cavity 18 for attachment to a connector 19 provided on the back of the lamp unit 10.

Contact between the lamp unit 10 and the mounting plate 6 and, in particular, the radiator 11 is optimised to allow good thermal conduction of the heat generated by the lamp unit 10 away from the lamp unit 10. The radiator 11 is provided with a plurality of deep grooves 20 to increase the surface area available for heat dissipation.

A covert light module 12 including LEDs which emit IR radiation rather than visible light may be located away from the lamp unit 10 in a hole provided in a rear portion of the housing 9. Accordingly, IR light will be transmitted in a generally upward and rearward direction for the benefit of 'friendly' pilots wearing NVGs.

Figure 6 is a sectional view showing a lamp unit 10 according to the invention. The lamp unit 10 comprises a metal container 21, a plastic optical unit 22, and an LED array on a ceramic substrate (shown together as 23). The LED array on its ceramic substrate 23 is attached to the back wall 24 of the container 21, the container 21 having a rim 25 which forms the four sides of the lamp unit 10. The rim 25 is stepped to from an integral spacer 26 that separates the optical unit 22 from the LED array 23 with a desired gap of about 1 mm.

Figure 7 shows a square LED array 23 containing thirty-six LEDs 27. The LEDs 27 are mounted in six horizontal strings 28 of six LEDs 27 on a square ceramic substrate with rounded corners. The strings 28 of LEDs 27 are connected to the power supply in parallel to ensure that should one LED 27 fail, only the other LEDs 27 in its string 28 will also be extinguished. Of course, it will be appreciated that the number of LEDs 27 in the illustrated LED array 23 can be varied, as can the configuration and arrangement of the strings 28.

Figure 8 shows an optical unit 22 which is moulded from plastic. The inner surface 29 in

use of the optical unit 22 bears a number of uniform convex lenses 30, whilst its outer surface 31 bears a number of straight-edged prisms 32.

The convex lenses 30 are arranged such that the light emitted by each LED 27 is collected by a lens 30: therefore, there is a common number of LEDs 27 and lenses 30. Accordingly, the convex lens array 33 is arranged to coincide with the LED array 23 when fitted in the lamp unit 10. It will be appreciated that the lens array 33 shown in Figure 8 is not intended for use with the LED array 23 of Figure 7, but is designed for use with an LED array 23 with fourteen LEDs 27 per string 28.

The prisms 32 are triangular in cross-section and project outwardly from the outer surface 31 of the optical unit 22 with an upright face 34 and a sloped face 35. This triangular shape of a prism 32 varies along a column of LEDs 27, so that each prism 32 is moulded as a ridge 32 in the outer surface 31 of the optical unit 22. Each ridge 32 extends vertically across the length of the LED array 23 immediately above a column of LEDs 27. Essentially, each convex lens 30 directs substantially all light emitted from its associated LED 27 towards an associated section of prism 32 positioned immediately above.

In addition to the shape of each prism 32 varying along the prism's length, the shapes of individual prisms 32 (i.e. the ridges 32) vary across the optical unit 22. Figure 8 shows that each prism 32 has an upright face 34, but the angle of the sloped face 35 varies across the array of prisms 32, such that the height of adjacent prisms 32 reduces gradually.

This graduation in the angles of the sloped faces 35 between adjacent prisms 32 allows an emitted light pattern in the horizontal plane to be produced that better approximates those specified by the governing aviation authorities. For example, the majority of the prisms 32 can be used to refract light away from the 35° direction towards the forward direction of the aircraft, more specifically between the angles of 0° and 20° where the greatest intensity is required. A minority of the prisms 32 can direct light to the higher angles of 20° to 110° to meet the required 5 candela in those directions.

An end prism 36 is provided a sloped face 35 angled in the opposite sense to the others: this end prism 36 is used primarily to refract light to the higher azimuthal angles of the required angular distribution.

Similarly, varying the slope in an orthogonal direction along the length of each prism 32 allows an angular distribution in the vertical plane to be formed meeting the required

distribution.

As the lens array 33 produces the desired light pattern, the plain plastic window 8 merely protects the lamp unit 10 and does not significantly alter the emitted light distribution.

It is to be appreciated that the above embodiment is merely illustrative and that variations and modifications which do not depart from the scope of the invention will be apparent to those skilled in the art.

For instance, whilst the embodiment described above deals both with the angular distribution of light intensity in the horizontal and vertical planes, an optical unit 22 could also be used to modify the angular distribution of light intensity in only one of the planes.

Furthermore, it will be noted that the optical units 22 disclosed above all use refraction to manipulate the direction of the light emitted from the LEDs 27. However, in addition to the use of refractive optics, the use of diffractive optics may be an equally effective method which remains within the scope of the invention. For example, a diffraction grating could be employed in the optical unit 22 rather than the prisms 32 described herein above. In addition, a combination of refractive and diffractive optics could be used, such as a lens array 33 to collect light and a grating to direct the angular emission of the light from the optical unit 22.

Variations in the design of the navigation light are also possible. For instance, Figure 9 shows an alternative navigation light assembly 1 intended for use with aircraft which fly at sub-sonic speeds. This differs most markedly from the above described embodiment in that the rear of the external portion is defined by a large solid metal heat-sink 37, rather than the thin-walled metal housing 9. In this embodiment, the lamp unit 10 is mounted directly to the front of the heat-sink 37, so that good thermal contact is established. This heat sink 37 is in direct contact with the atmosphere and consequently can radiate heat rapidly to its surroundings.

Accordingly, reference should be made to the appended claims and other general statements herein rather than to the foregoing specific description as indicating the scope of the invention.

CLAIMS

- 5 1. A warning light for an aircraft comprising an array of LEDs and an optical unit held in front of the LED array, the optical unit incorporating optical means for propagating fractions of the light emitted from the LEDs in selected directions in accordance with a predetermined angular distribution.
- 10 2. A warning light for an aircraft comprising an array of LEDs and an optical unit held in front of the LED array, the optical unit incorporating optical means which redirects at least some of the light which would otherwise be emitted from the LEDs in a substantially lateral direction relative to the orientation of the aircraft, and emits a fraction of that light in a substantially forward direction.
- 15 3. A warning light as claimed in claim 1 or claim 2, wherein the optical unit is held relative to the LED array such that substantially all of the light emitted from the LEDs positioned directly beneath the optical unit is incident upon the optical unit.
- 20 4. A warning light according to any preceding claim, wherein the optical unit comprises refractive and/or diffractive optical means.
5. An optical unit according to any of claims 1 to 4, comprising first optical means for collecting light emitted from the LED array and second optical means for propagating the collected light in the required direction.
- 25 6. A warning light according to claim 5, wherein the first optical means comprises a plurality of lenses to collect the incident light from the LEDs.
7. A warning light according to claim 6, wherein each LED is associated with a separate lens.
- 30 8. A warning light according to claim 7, wherein each of the lenses is disposed immediately in front of its associated LED.
- 35 9. A warning light according to any of claims 5 to 8, wherein the second optical means comprises one or more prisms to propagate the collected light in accordance with a desired angular distribution.

10. A warning light according to claim 9, wherein a plurality of prisms extend at least the length and/or width of the LED array to form of series of ridges on the outer surface in use of the optical unit.

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11. A warning light according to claim 10, wherein the array of LEDs comprises a plurality of strings of LEDs, the strings being connected in parallel and each string comprising a plurality of LEDs connected in series and the prisms extend across the LEDs of more than one string of LEDs.

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12. A warning light according to claim 11, wherein the strings of LEDs and the prisms are disposed orthogonally with respect to each other.

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13. A warning light according to any preceding claim, wherein the optical unit comprises a transparent body having first and second opposed faces, the first face being provided with first optical means in the form of a plurality of convex lenses and the second face being provided with second optical means in the form of one or more prisms, the relative disposition of the or each prism and the convex lenses being such as to propagate light from the unit in accordance with a predetermined angular distribution.

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14. A warning light according to any preceding claim, wherein the optical means is formed as an integral part of the optical unit.

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15. A warning light according to claim 14, wherein the optical unit is a moulded, plastic element.

16. A warning light according to any preceding claim, further comprising spacing means for positioning the optical unit at a required distance from the LEDs in the array.

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17. A warning light according to claim 16, wherein the spacing means is formed integrally with the optical unit.

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18. A warning light according to claim 16, wherein the LEDs are encapsulated in a potting compound and the potting compound is formed at the required depth to provide the spacing means.

19. A warning light according to any preceding claim, wherein a gap of up to 5 mm is

provided between the LEDs and the optical unit.

20. A warning light according to claim 19, wherein a gap of between 0.5 mm and 2 mm is provided.

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21. A warning light according to any preceding claim, further comprising one or more IR LEDs.

10 22. An optical unit for use with an LED array in an aircraft warning light, the unit comprising optical means for propagating fractions of the light emitted from the LEDs in selected directions in accordance with a predetermined angular distribution.

15 23. An optical unit for use with an LED array in an aircraft warning light, the unit comprising optical means which redirects at least some of the light which would otherwise be emitted from the LEDs in a substantially lateral direction relative to the orientation of the aircraft, and emits a fraction of that light in a substantially forward direction.

24. An optical unit according to any claim 22 or 23, comprising refractive and/or diffractive optical means.

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25. An optical unit according to any of claims 22 to 24, comprising first optical means for collecting light emitted from an LED array and second optical means for propagating the collected light in the required direction.

25 26. An optical unit according to claim 25, wherein the first optical means includes a plurality of lenses disposed on one surface of the unit, each lens positioned to correspond with the position of an LED in the array with which the unit is intended to be used.

30 27. An optical unit according to claim 25 or 26, wherein the second optical means comprises one or more prisms disposed on an opposite surface of the unit to that of the first optical means.

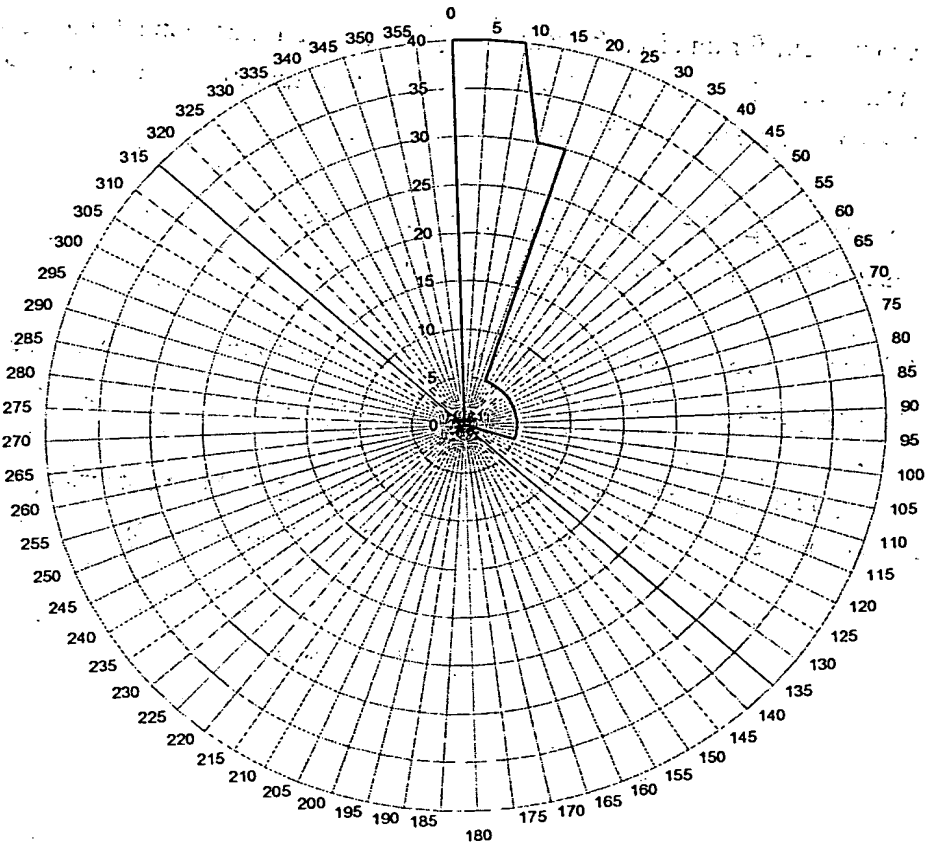
35 28. An optical unit for use with an LED array in an aircraft warning light, the unit comprising a transparent body having first and second opposed faces, the first face being provided with a plurality of convex lenses and the second face being provided with one or more prisms, the relative disposition of the or each prism and the convex lenses being such as to propagate light from the unit in accordance with a predetermined angular distribution

29. An optical unit according to claim 27 or 28, wherein the prisms extend at least the length or width of the LED array and form a series of ridges.
- 5 30. An optical unit according to any of claims 22 to 29, wherein the optical means is formed as an integral part of the optical unit.
31. An optical unit according to claim 30 comprising a moulded plastic element.
- 10 32. A lamp unit for an aircraft warning light comprising an optical unit as claimed in any of claims 22 to 31, together with an LED array and spacing means for holding the optical unit at a fixed distance from the LEDs in the array.
- 15 33. A warning light for an aircraft substantially as hereinbefore described with reference to Figures 2 to 5 and Figure 9 of the accompanying drawings.
34. A lamp unit for an aircraft warning light substantially as hereinbefore described with reference to Figure 6 of the accompanying drawings.
- 20 35. An optical unit for use in an aircraft warning light substantially as hereinbefore described with reference to Figure 8 of the accompanying drawings.



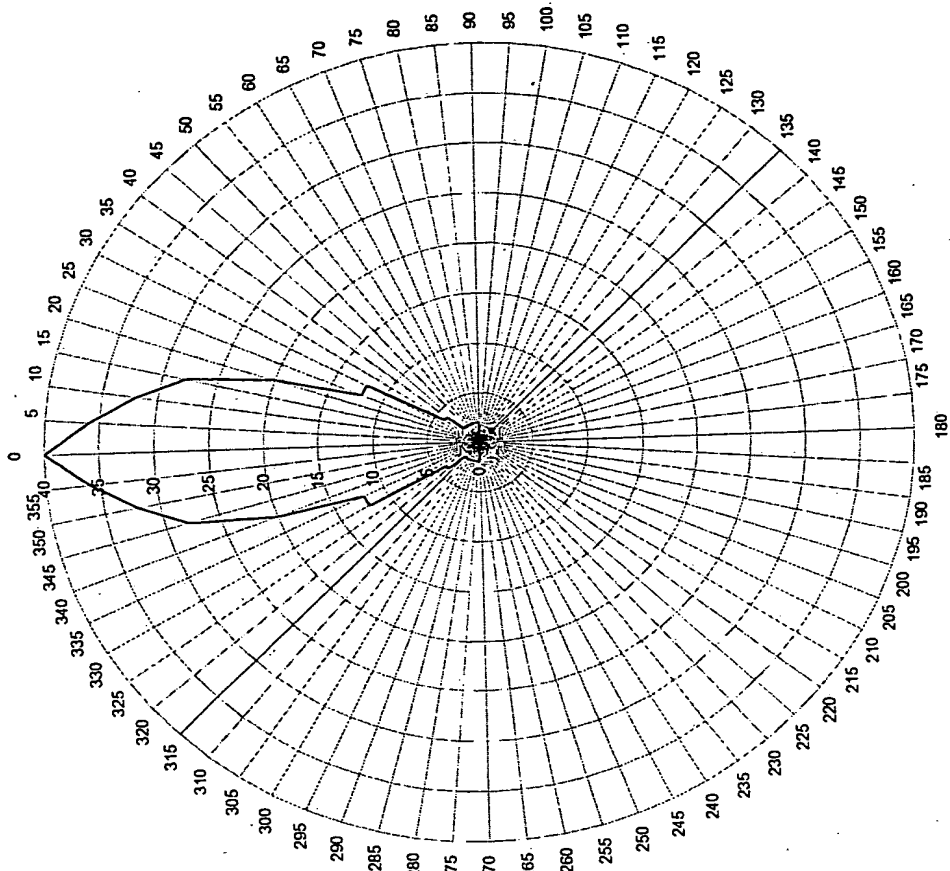
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Fig. 1a



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Fig. 1b



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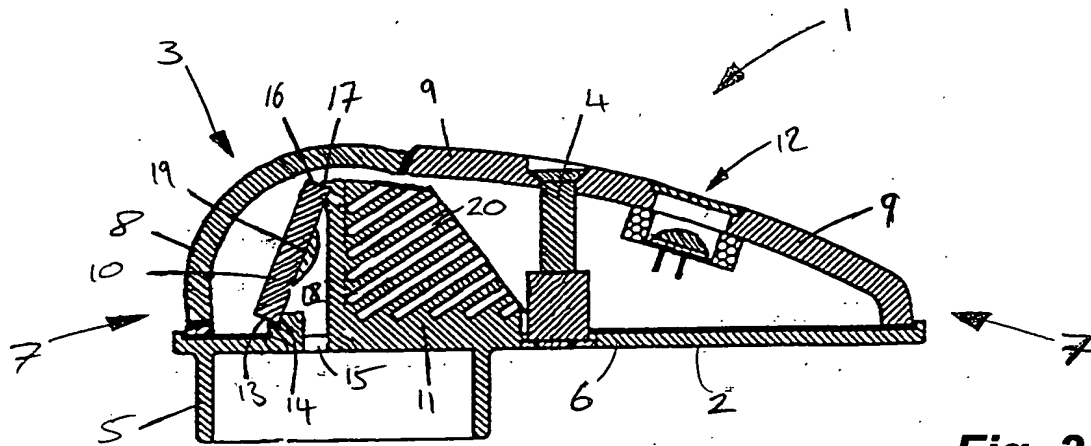


Fig. 3

SECTION X-X

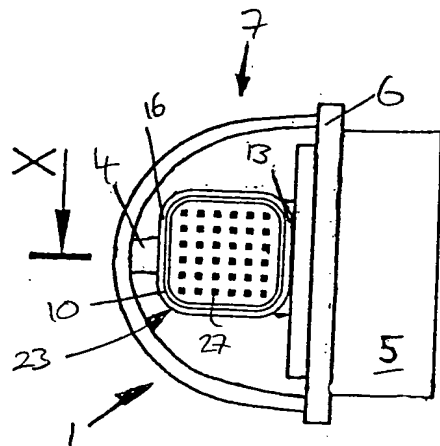


Fig. 2

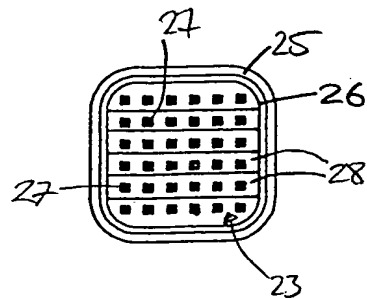
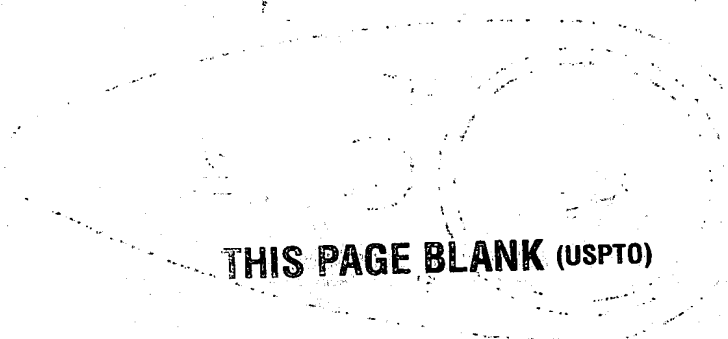


Fig. 7



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Fig. 4

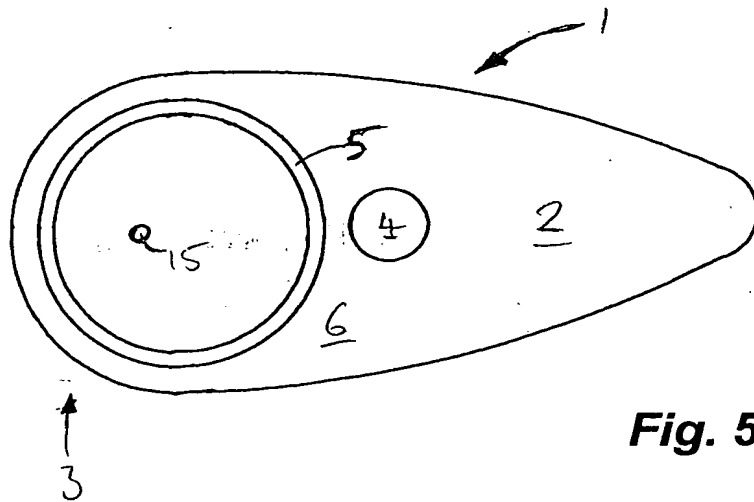
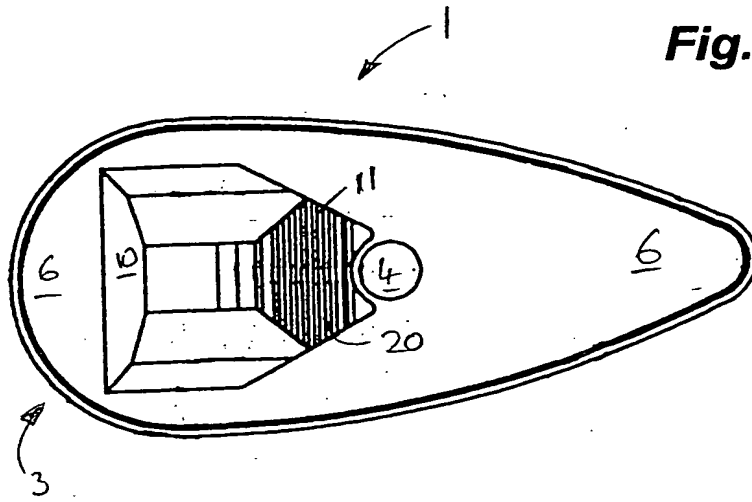


Fig. 5

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Fig. 6

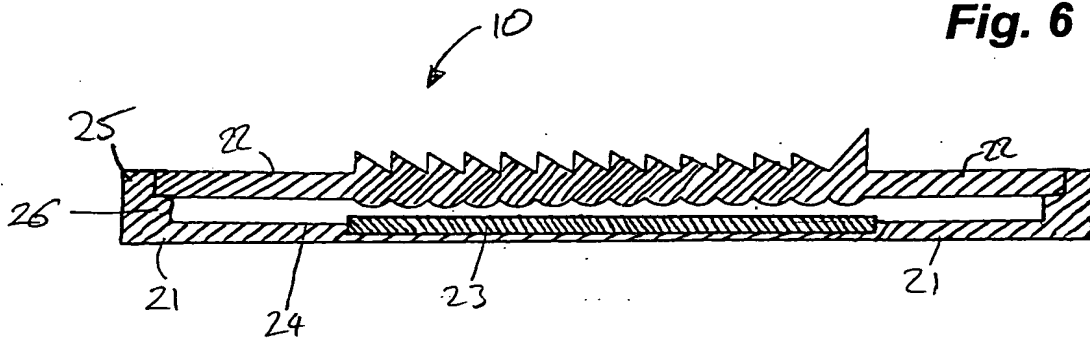


Fig. 8

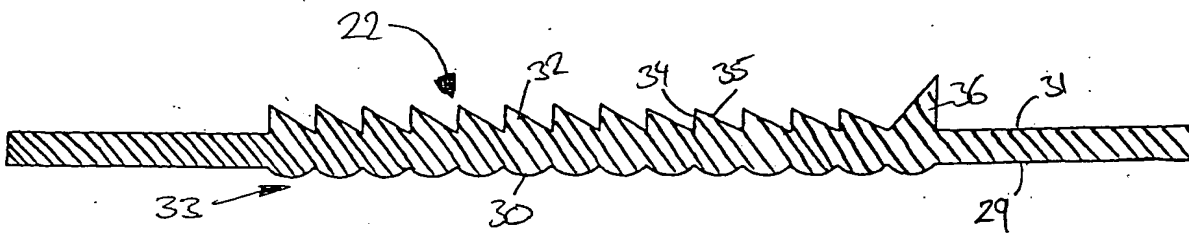
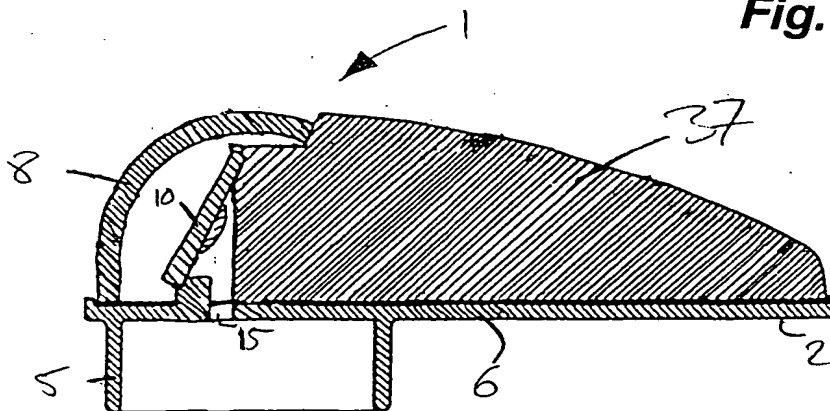


Fig. 9



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